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Title: IMAGE TRACKING SYSTEM AND METHOD

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FIELD OF THE INVENTION

The present invention relates to an image tracking system, and more particularly to an image tracking system for video conferencing or computer based image communication applications.

BACKGROUND OF THE INVENTION

Increases in computer processor speeds into the Ghz region, and increases in bandwidth capacities and transmission speeds of networking devices are providing personal computer users with the capabilities of watching live camera generated images as they are transmitted across the internet.

These advances have increased the quality of transmitted images and feasibility of video conferencing using personal computers in both the home and the office. The importance of video conferencing for quick and efficient communication in the business world places a need for effective video conference systems for the personal computer which use low cost commercial components to achieve dynamic features suited to a live conference environment.

There are many instances during a video conferencing session whereby the user is required to move from behind his or her computer in order to demonstrate or present a device, object or corporate information of some sort. To achieve such a dynamic video conferencing environment, an image tracking system which includes an image capture device such as digital camera must effectively track a user's movements. Such a system must be easily installed on the computer and comprise a light weight, low cost and easily manufacturable mechanical components for providing efficient camera movement.

United States Patent No. 4,264,928 describes a video conference system which uses a servo-motor controlled mirror to project the image of a person at a conference room table onto a TV camera when he or

she talks into a microphone. The invention provides a method of tracking a person when they speak into a microphone. Based on the strength of the signals received from each persons microphone, the servo-motors position the mirror to project the image of the person talking onto the TV camera. This system is limited to televising conferences where all participants are in the same room rather than providing video conferencing for participants in remote geographical locations. Furthermore, the system incorporates motors for rotating a mirror rather than rotating the inherent weight of the TV camera.

United States Patent No. 5,416,513 describes a video camera for tracking an object by comparing a specific color picked from the image to a specific color stored as a reference. Based on the processed results from comparing the specific color stored as a reference and the image received from the camera, a motor rotates and tilts the camera to follow the region in which the specific color signal detected in the image is larger than in others. However, a mechanical structure for providing efficient tilt and pan movements has not been defined.

United States Patent No. 5,606,368 describes a pan and tilt mounting system for providing movement for cameras and related devices. The use of a cable drive in the system eliminates the inaccuracy inherent in similar gear driven systems. The invention does not pay particular attention to the mounting position of the motors which affects the movement efficiency. The invention discusses a tilt motor for controlling tilt movement and a pan motor for controlling rotational (panning) movement, whereby the mass of the tilt motor is subject to the rotational movement provided by the pan motor. This type of “motor loading” configuration reduces the efficiency of the pan motor and increases the torque requirements.

Accordingly, there is a need for an image tracking system for video conferencing or computer based image communication applications which is capable of effectively and efficiently tracking the movements of a user, which is relatively inexpensive to manufacture and which is easily operable.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention in one aspect to provide image tracking system for use with an image capture device which obtains digitized image frames of an object, the image tracking system comprising:

(a) a support for holding the image capture device;

(b) a processing device for determining an object location value for the object based on the digitized image frames generated by the image capture device;

(c) a position control device coupled to the support for, in use, rotating the support and the image capture device mounted therein about two axes based on the object location such that the object remains within a center region of each of the digitized image frames, said position control device comprising:

  (i) a base;

  (ii) a first motor mounted on the base for generating a first rotational movement based on the object location and a first rotatable member mounted to the base for rotation about a first axis, said first rotatable member being connected to the first motor; and

  (iii) a second motor mounted on the base for generating a second rotational movement based on the object location and a second rotatable member comprising the support mounted to the first rotatable member for rotation about a second axis and being connected to the second motor.

In another aspect, the present invention provides an image tracking system for use with first and second image capture devices which obtains digitized image frames of an object, the image tracking system comprising:

(a) a first support for holding the first image capture device and a second support for holding the second image capture device;

(b) a processing device for determining an object location value for

the object based on the digitized image frames generated by the image capture device;

(c) a position control device coupled to the support for, in use, rotating the first and second supports and the first and second image capture devices mounted therein about <u>four axes</u> based on the object location such that the object remains within a center region of each of the digitized image frames, said position control device comprising:

(i) a base;

(ii) a first motor mounted on the base for generating a first rotational movement based on the object location and a first rotatable member mounted to the base for rotation about a first axis, said first rotatable member being connected to the first motor;

(iii) a second motor mounted on the base for generating a second rotational movement based on the object location and a second rotatable member mounted to the first rotatable member for rotation about a second axis and being connected to the second motor;

(iv) a third rotatable member comprising the first support and a fourth rotatable member comprising the second support, said third and fourth rotatable members being mounted on the second rotatable member, at least one of said third and fourth rotatable members being rotably mounted to said second rotatable member; and

(v) a third motor mounted on the base for providing relative rotation between said third and said fourth rotatable members.

In another aspect, the present invention provides a method of tracking an object, said method comprising the steps:

(a) obtaining a series of digitized image frames from the image capture device;

(b) identifying the object within each of the digitized frames; and

(c) providing a first rotational movement to the image capture device about a first axis using a first motor and providing a second rotational movement to the image capture device about a second axis using a second motor such that the object remains within a center region of each of the digitized frames.

In another aspect, the present invention provides a tension regulation device for controlling the amount of tension applied to a tendon, said tension regulation device comprising:

(a) a platform;

(b) a resilient column rotatably mounted on the platform and having a cross-section with a first radius;

(c) a splined column rotatably mounted on the platform and having a plurality of spline members extending radially and having a cross-section with a second outer radius, said splined column being adapted to receive a portion of the tendon therearound;

(d) said resilient column being spaced apart from said splined column and rotatably mounted on said platform at a distance equal to slightly less than the sum of the first and second radius; and

(e) such that in the absence of tension the spline members slightly deform said resilient column to restrict rotational movement of said spline column and said tendon and in the presence of tension, the spline members are forced to travel along the surface of said resilient column and to unwind the portion of the tendon around the splined column.

In another aspect, the present invention provides a tendon motor pulley for coupling a tendon length to a motor shaft, said tendon motor pulley comprising:

(a) a first disc;

(b) an second disc, the first and second discs having facing surfaces;

(c) a hub positioned concentrically between said first and second discs; and

(d) at least one engagement means extending between the first and second discs and located radially outwardly from the hub, whereby a tendon can travel freely around the hub and the engagement means engages the tendon.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

Fig. 1 is a block diagram of a preferred embodiment of the image tracking system of the present invention;

Fig. 2 is a perspective view of a position manipulating device of the image tracking system of Fig. 1;

Fig. 3A is a vertical cross sectional view of the position manipulating device illustrated in Fig. 2 along the line AA';

Fig. 3B is a horizontal cross sectional view of the position manipulating device illustrated in Fig. 3A along the line BB';

Figs. 4A and 4B are cross-sectional views of the collar member of the image tracking system of Fig. 1;

Fig. 5A is a top view of the neck member of the image tracking system of Fig. 1;

Fig. 5B is a side view of the neck member of the image tracking system of Fig. 1;

Fig. 6A is a top view of the camera support member of the image tracking system of Fig. 1

Fig. 6B is a side view of the camera support member of the image tracking system of Fig. 1

Fig. 7 is a cross sectional view of the neck member of the image tracking system of Fig. 1;

Figs. 8A and 8B are top views of the tension release mechanism installed in the neck member of the image tracking system of Fig. 1;

Figs. 9A and 9B are bottom views the tension release mechanism

installed within the collar member of the image tracking system of Fig. 1;

Figs. 10A and 10B are perspective views of the assembled tendon motor pulley of the image tracking system of Fig. 1;

Figs. 10C and 10D are perspective views of the upper and lower tendon wheels, respectively, of the image tracking system of Fig. 1;

Figs. 11A and 11B are cross-sectional views of the assembled tendon motor pulley, shown engaged by a tendon;

Fig. 12 is functional flow diagram illustrating the functionality of the image tracking program of the image tracking system of Fig. 1;

Fig. 13A is a front view of an alternative embodiment of the position manipulation device of image tracking system of Fig. 1;

Fig. 13B is a side view of the position manipulation device of Fig. 13A;

Fig. 13c is a top view of the position manipulation device of Fig. 13A; and

Fig. 14 is a screen capture of the CONTROL SCREEN™ user interface generated by the user interface software of the image tracking system of Fig. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Reference is first made to Fig. 1, which show a functional block diagram of the image tracking system **10** made in accordance with a preferred embodiment of the invention. The image tracking system **10** comprises a hardware subsystem **12** and software subsystem **35**. The hardware subsystem **12** includes a digital video camera **16**, a motor driver **24**, a first motor device **18** and a second motor device **22**. The software subsystem **35** includes a user interface **38** and an image capture and processing stage **40**. The image capture and processing stage **40** comprises a camera driver component **42**, an image processing component **44** and a motor control interface component **46.**

OVERVIEW

Generally, the image tracking system **10** processes digitized images

that are received from an image capture device such as camera **16**. Image processing of the digitized images generates a location value corresponding to the object image. Based on this location value, appropriate control signals are generated for controlling the orientation and position of the video camera. The orientation and position of the camera is varied in order for the camera to track the movement of an object image within the digitized image, wherein the object image is a human subject. While the following discussion will assume that camera 16 is a digital video camera, it should be understood that any type of image processing device could be used (e.g. analog video camera) in conjunction with an appropriate data conversion device for generating digital data for use by image tracking system 10.

Still referring to Fig. 1, the user interface **38** provides features such as a software generated graphical window for viewing the camera generated image, also allowing the user to control the size and quality of the image within the window. Other features of the user interface **38** include the ability to override the image tracking function of the image tracking system **10** in favour of user positioning, whereby the user can directly position and move the camera **16** by appropriately operating a computer pointing device.

The camera driver **42** provides the necessary synchronization and data accessing protocol, for interfacing image data corresponding to digitized image frames generated by the video camera **16** to the image processing component **44**. The camera driver **42** ensures that image data is presented to the image processing component **44** at the required rate (any rate) and that the image processing component **44** can access image data corresponding to any region (an object image) within each of the digitized image frames. The camera driver **42** essentially provides the necessary interfacing between different cameras and manufacturer-supplied drivers, and the image processing component **44**.

Once the image data is received by the image processing component **44** of the software subsystem **35**, a color tracking algorithm is used for determining an area of color associated with a human subject within the

digitized image. The color associated with a human subject could be pre-set to be a certain labelling color (i.e. a blue colored wearable button) or it can be the person's skintone. The color region of a human subject is located within the digitized image by scanning image pixels. For efficient real time color detection, the pixel area occupied by the digitized image is scanned radially, where the radial scanning starts at the center of the image, moving progressively outwards toward the border of the image. While the following discussion will assume that the color region to be analyzed for a particular human subject is in fact their skintone, it should be understood that any other type of color region could be used for subject tracking and identification.

Skintone detection is based on color values determined from the RGB-24 video signals from the video camera **16**. The pixels depicting skintone are detected and processed in order to generate a position of optimal correlation, which corresponds to a center point within a prominent skintone region. This calculated center point is called a centroid and has coordinate position value, which is used to detect image movement and generate camera movement signals for tracking the skintone area of the human subject as he or she moves.

The motor control interface **46** within the software subsystem **40** communicates with a position control device referred to as a motor driver **24** using a communication link **48**, such as a direct link, an RS232 serial link, USB or wireless link. The motor driver **24** comprises a microcontroller device (see Fig. 3A, reference character **114**) with programmed firmware for receiving and processing position movement instructions from the motor control interface **46**.

The motor control interface **46** transmits a two byte position movement instruction frame to the motor driver **24**. The instruction frame comprises: two control bits for indicating a selected servo-motor for positional manipulation, an 8-bit word for generating the value of positional movement or manipulation required by the selected servo-motor, and control bits for indicating the status of the servo-motors (e.g. standby mode). The 8-bit word

representing positional movement, corresponds to 256 discrete position values, wherein each position value generates a specific angular displacement for either the first motor **18** or the second motor **22**. In accordance with the present invention the first and second motor **18**, **22** are servo-motors responsible for the rotation movement and tilt movement of the camera **16** respectively. However, it will be appreciated that other types of motor device, data communication protocol, and position resolution values may be used in association with the image tracking system 10, without departing from the scope of the present invention.

The motor driver **24** controls the positional movement of the first motor **18** and the second motor **22** by converting the corresponding values of positional movement (0-255) received from the motor control interface **46** (command frames) to a first and second pulse width modulated (PWM) control signal. The first and second PWM control signals are responsible for generating rotational movement for the first and second motors **18**, **22**. The PWM signal is a pulse train having a fixed period (e.g. 20 ms) with a variable pulse width (e.g. 1-2 ms). Each value of positional movement (0-255) received by the motor driver generates a PWM signal of specific pulse width value.

Once the PWM signal from the motor driver **24** is received by the designated motor (first motor **18** or second motor **22**), based on the pulse width of the PWM signal, the designated motor's shaft rotates to a specific angular position somewhere in the range of 0-180 degrees. The motor **18**, **22** positions are normally initialized to a mid-range position of 90 degrees by applying a 1.5ms PWM signal to their input. By varying the PWM signal between 1.5ms and 1ms, the first and second motor **18**, **22** shafts will rotate between 90 and 0 degrees. Similarly, by varying the PWM signal between 1.5ms and 2ms, the designated motor's **18**, **22** shaft will rotate between 90 and 180 degrees.

IMAGE TRACKING HARDWARE

Fig. 2 shows a three-dimensional perspective view of a position

manipulating device **70** for both mounting and varying the positional movement of the camera (not shown). The position manipulating device **70** comprises a collar member **80** which provides the first rotational movement. The second rotatable member of the position manipulating device **70** is a neck member **72** which provides the second rotational movement.

Position manipulating device **70** also includes a direction indicator **71** mounted on the front surface of position manipulating device **70** which is adapted to indicate operation to the user. Specifically, direction indicator **71** comprises an UP indicator **71a**, a DOWN indicator **71b**, a LEFT indicator **71c**, a RIGHT indicator **71d** and a TRACKING indicator **71e**. UP indicator **71a**, a DOWN indicator **71b**, a LEFT indicator **71c**, and RIGHT indicator **71d** all indicate the direction in which position manipulating device **70** is moving. TRACKING indicator **71e** indicates to the user that image tracking system **10** has identified the subject and is tracking the subject.

The neck **72** has a hemispherical shape which supports and secures an annular shaped camera support member **75**. The video camera (not shown) is mounted on the position manipulation device **70** by means of the camera support member **75** attached to the neck **72**. The position manipulating device **70** further includes a stationary base member **90** for contacting a support surface **68** and supporting the collar member **80**, the neck **72** and the camera support member **75**. The first rotational movement of the collar **80** is a pan movement (rotation) and the second rotational movement of the neck **72** is a tilt movement.

Therefore, the video camera (not shown in Fig. 2) is rotated by means of the pan movement of the collar **80**, whilst being simultaneously tilted by the tilt movement of the neck **72**. The first motor **18** generates the first rotational movement referred to as the pan movement of the collar member **80**, and the second motor **22** generates the second rotational movement referred to as the tilt movement of the neck **72**.

Fig. 3A shows a vertical cross sectional view along the line AA' of the position manipulating device **70** illustrated in Fig. 2. The base member **90** is hollow and houses a mounting member **100**, the motor driver which

comprises a microcontroller device **114**, and both the first and second motors **18**, **22**. The mounting member **100** rigidly attaches to a set of four securing points **92** (only two are shown) on the base member **90** by means of four securing screws **93** (only two are shown). The mounting member **100** includes a first vertical shaft portion **108** for engaging the collar member **80**.The collar member **80** comprises a cylindrical cavity region enclosed within a cylindrical housing **82**, wherein the cavity region receives the first vertical shaft portion **108** of the mounting member **100** such that the collar member **80** is rotatably mounted on the first vertical shaft portion **108**. Consequently, the base member **90** and attached mounting member **100** are stationary with respect to the rotatable collar member **80**. The pan movement of the collar member **80** has a first plane of rotation **127** about a fixed first rotation axis, as defined by **125**. The pan movement of the collar member **80** defines the pan movement of the position manipulating device **70**.

Fig. 3B shows a horizontal cross sectional view along the line BB' of the position manipulating device **70** illustrated in Fig. 2. Specifically, the mounting member **100** is shown having four securing points **92** and the securing screws **104** which couple the motors **18, 22** to the under surface **102** of the mounting member **100**. Further, first vertical shaft portion **108** is shown in cross-section located at the center of mounting member **100**. Also shown is a motion restricting member **69** which is adapted to restrict pan motion of the collar **80** to within a range of approximately 160° as indicated by angle A. It should be understood that other movement ranges could be implemented within position manipulating device **70** by suitably changing the configuration of motion restricting member **69**. The first tendon member **95** is shown passing through a first opening **103** and extending around first vertical shaft portion **108**.

As will be discussed in more detail in Figs. 9A and 9B, a tension release mechanism **255** comprises a second rotatable splined column **268** and a second rotatable second column **262** which are mounted on a platform **290** and rotatably coupled to first vertical shaft **108**. The lateral

separation between the second splined column **268** and the second rotatable second column **262** is less than the sum of their radii. The tension release mechanism **255** protects the first tendon member **95** from breaking due to the collar **80** being physically forced to rotate when the first rotatable motor shaft **96** of the first motor **18** is either stationary, or rotating in the direction opposing that of the induced force, as will be further discussed in respect of Figs. 9A and 9B.

The microcontroller **114** is mounted on an electrical circuit board **110** and receives position movement instruction frames from the motor control interface **46** via an electrical connection **118** connected to an electrical connector **117** mounted on the electrical circuit board **110**. It will be appreciated that the position movement instruction frames from the motor control interface **46** may be transmitted to the electrical circuit board by any suitable communications means, such as a direct link, an RS232 serial link, USB or wireless link. The microcontroller **114** processes the received movement instruction frames for the purpose of controlling the movement direction and magnitude of the collar **80** and neck **72** by means of motors **18** and **22** respectively.

The neck **72**, further comprises a pair of cylindrically shaped securing members **142** (only one shown in Fig. 3A) for rotatably connecting the neck **72** to a pair of retaining slots **131** (only one shown) located at the upper securing portion **81** of the collar member **80**. The neck **72** rotatably tilts relative to a pivot point, wherein the pivot point is defined by the engagement of the pair of cylindrically shaped securing members **142** on the neck **72** with each pair of retaining slots **131**.

As the neck **72** tilts about the pivot point, it has a second plane of rotation **122** about a second rotation axis, as defined by **120**. The pan movement of the collar **80** relative to the tilt movement of the neck **72** is such that the second rotation axis, as defined by **120**, of the neck **72**, rotates about the first fixed rotation axis, as defined by **125**, of the collar **80**. In the current embodiment of the present invention, the first fixed plane of rotation, as defined by **127**, of the collar **80** and the second plane of rotation, as

defined by **122**, of the neck **72** are perpendicular. The tilt movement of the neck **72** defines the tilt movement of the position manipulating mechanical structure **70**.

The first motor **18** comprises a first rotatable motor shaft member **96** and the second motor **22** comprises a second rotatable motor shaft member **98**. Both motors **18**, **22** are stationary with respect to the neck **72** and collar **80** and are connected to the under surface **102** of the mounting member **100** by means of a second set of four securing screws **104** (only two are shown). The first motor shaft member **96** of the first motor **18** has a third rotation axis (not shown) which is longitudinally concentric with the first motor shaft member **96**. Similarly, the second motor shaft member **98** of the second motor **22** has a fourth rotation axis (not shown) which is longitudinally concentric with the second motor shaft member **98**. Both motors **18**, **22** have been secured to the mounting member **100**, wherein the mounting member **100** is stationary relative to the rotatable neck and collar member **72**, **80**.

The third rotation axis of the first motor shaft **96** and the fourth rotation axis of the second shaft **98** are stationary and fixed relative to each other. Therefore, each motor **18**, **22** independently provides pan and tilt movement for the collar **80** and neck **72** without for example the first motor **18** carrying the mass or load of the second motor **22**. Consequently, the mounting position of the motors (**18** and **22**) is such that neither the first motor **18** providing pan movement nor the second motor **22** providing tilt movement carries the mass or load of the other motor (**18** or **22**).

A first tendon member **95** couples the rotational movement of the first motor shaft member **96** to the collar member **80** which in turn causes the collar **80** to rotate about the first vertical shaft portion **108**. The first tendon member **95** comprises a first segment and a second segment, where each segment has a first end and a second end. At the first end, the first segment of the first tendon **95** is attached to the circumference of the first motor shaft member **96**. Similarly, at the first end, the second segment of the first tendon **95** also attaches to the circumference of the first motor shaft

member **96**.

Consequently, at the first end, the first and second segments of the first tendon member **95** form a loop around the first motor shaft **96**. As the tension on the first end of the first tendon **95** increases due to the first motor shaft **96** rotating, the attachment of the first and second segments to the first shaft member **96** avoids any slipping of the first tendon **95** relative the first motor shaft **96**. It will be appreciated that in accordance with the present invention, the first tendon member **95** is defined as a segment of string, cord, rope, wire or other filament that under pulling tension at one end can cause movement at the other.

The collar member **80** further comprises a second vertical shaft portion **84** located near the base of the collar **80**, wherein the second vertical shaft portion **84** receives the second end of the first tendon member **95** for coupling the first motor shaft **96** rotation to the collar **80**. The first vertical shaft **108** is concentric with the second vertical shaft **84**, wherein the second vertical shaft **84** rotates about the first vertical shaft **108**.

At the second end, the first segment of the first tendon **95** is attached to a fixed point (not shown) on the circumference of the second vertical shaft portion **108** of the collar member **80**. Also, at the second end, the second segment of the first tendon **95** is attached to a fixed point (not shown) on the circumference the second vertical shaft portion **108**. Consequently, at the second end, the first and second segments of the first tendon member **95** form a loop around the second vertical shaft portion **108**. As the tension on the second end of the first tendon **95** increases due to the first motor shaft **96** rotating, the attachment of the first and second segments to the second vertical shaft portion **108** avoids any slipping of the first tendon **95** relative the second vertical shaft portion **108**. The first tendon member **95** passes through a first opening **103** in the mounting member **100** when connected between the first motor shaft member **96** and the second vertical shaft portion **108** of the collar **80**. By connecting the first tendon **95** between the first motor shaft member **96** of the first motor **18** and the second vertical shaft portion **108** of the collar member **80**, the rotation of the first motor shaft

member **96** is coupled through the first tendon **95** to the second vertical shaft portion **84** causing the pan movement of the collar **80**.

Clockwise rotational movement of the first motor shaft **96**, as defined by directional arrow **B**, is transferred through the first tendon **95** to the collar member **80**, causing the first tendon **95** to rotate or pan the collar **80** in a clockwise motion, as defined by directional arrow **B'**. Conversely, anti-clockwise movement of the first shaft **96** is transferred through the first tendon **95** to the collar member **80**, causing the first tendon **95** to rotate or pan the collar **80** in an anti-clockwise motion. The first fixed plane of rotation, as defined by **127**, of the collar **80** rotates about the first fixed rotation axis, as defined by **125**, wherein the first fixed rotation axis, as defined by **125**, is referred to as the major rotation axis. Hence, in accordance with the present invention, the major rotation axis which occurs due to the pan movement is fixed.

A second tendon member **99** couples the rotational movement of the second motor shaft member **98** to the neck **72**, which in turn causes the neck **72** to tilt about the pivot point **142** defined by the engagement of the neck **72** with each pair of retaining slots **131**.

The second tendon member **99** comprises a first end, a central portion, and a second end located at the opposite end to the first end. At the first end, the second tendon **99** is attached to the circumference of the second motor shaft member **98**. Similarly, the second end of the second tendon **99** also attaches to the circumference of the second motor shaft member **98**. The length of tendon between the two end points is extended from the second motor shaft **98** to the neck member, where the central portion of the tendon **99** is attached to the neck **72** by means of a first slit region **74** and a second slit region **76** located at opposing positions on the body of the neck **72**. A cavity region within the hemispherical shaped neck **72** provides a means for passing the central portion of the second tendon member **99** through the neck **72**. The central portion of the second tendon member **99** is passed through the hollow region of the neck **72** by passing between the first and second slit region **74**, **76** (for a clearer

illustration of one of the slit regions, refer to Fig. 7).

Consequently, the first end and second end of the second tendon member **99** form a loop around the second motor shaft **98** and the neck **72**. As the tension on the first and second end of the second tendon **99** increases due to the second motor shaft **98** rotating (clockwise and anti-clockwise), the attachment of the first and second ends to the second shaft member **98** avoids any slipping of the second tendon **99** relative the second motor shaft **98**. It will be appreciated that in accordance with the present invention, the second tendon member **99** is defined as a segment of string, cord, rope, wire or other filament that by applied tension at one end can cause movement at the other.

Referring to Fig. 7, the second tendon **99** is placed within each slit region **74** (only **74** shown) and pushed to the base location **148** of the slit **74**, where the second tendon rests against the body of the neck as it exits the neck towards the second shaft member **98.**

As illustrated in Fig. 3A, a hollow bore region within the first vertical shaft **108** provides a channel for passing the second tendon **99** between the second motor shaft **98** and the neck **72**. The second tendon member **99** passes through a hollow region of the neck **72** and exits the neck **72** at the first and second slit region **74**, **76** locations.

Both portions of the second tendon **99** exiting the slit regions **74, 76** pass through a second opening **86** (also see Fig. 9A) at the top portion of the collar member **80** and a third annular opening **109** in the first vertical shaft **108** before connecting to the second motor shaft member **98** by means of the hollow bore of the first vertical shaft **108**. The rotation of the second motor shaft member **98** is coupled through the second tendon member **99** to the first or second slit region **74**, **76** causing the tilt movement of the neck **72** about the pair of pivotal points, defined by the engagement of the pair of cylindrically shaped securing members **142** (only one shown) on the neck **72** with each pair of retaining slots **131**.

Clockwise rotational movement of the second motor shaft **98**, as defined by directional arrow **C**, is coupled through the second tendon **99**

to the first slit region **74** on the neck **72**, causing an applied downward tension force on the first slit region **74**. This subsequently causes tilt movement of the neck **72** about the pair of pivotal points, defined by the engagement of the pair of cylindrically shaped securing members **142** on the neck **72** with each pair of retaining slots **131**. Directional arrow **C'** shows the direction of tilt movement for the neck as a result of the clockwise rotation of the second motor shaft **98**. Conversely, anti-clockwise movement of the second motor shaft **98** is coupled through the second tendon **99** to the second slit region **76** on the neck **72**, causing an applied downward tension force on the second slit region **76**. This causes tilt movement of the neck **72** about the pair of pivotal points in an opposing direction of rotation to that indicated by directional arrow **C'**.

The second plane of rotation, as defined by **122**, of the neck **72** rotates about the second rotation axis, as defined by **120**, wherein the second axis of rotation is referred to as a minor rotation axis. Hence, the minor rotation axis which occurs as a result of the tilt movement rotates about the fixed major rotation axis which occurs due to the pan movement.

In accordance with a preferred embodiment of the present invention, the position of the first and second tendons **95**, **99** are configured so that the respective pan and tilt movements do not apply additional unwanted tension on either tendon member (**95** or **99**). In other words, the movement of both the first tendon **95** and second tendon **99** are mutually independent of one another and neither rotatable member (neck **72** and collar member **80**) affects the other's movement. This is achieved by connecting the second tendon **99** in an approximately straight line path between the second motor shaft **98** and the neck **72**, whereby the second tendon is oriented so that a substantial portion of the second tendon is aligned with the stationary first rotation axis. As the first tendon member **95** provides pan movement, the minor axis of rotation corresponding to the tilt movement rotates about the second tendon member **99**. Therefore, no unwanted additional tension is applied to the second tendon **99** as a result of the pan movement about the major axis of rotation. By connecting a

tendon which provides a minor axis of rotation, in a straight line between its motor shaft and movement actuating member (e.g. neck member or wheel mechanism), such that movement about a major axis of rotation (e.g. pan movement) causes the minor axis to rotate about the tendon corresponding with the minor axis, the movement about the major axis will not affect movement about the minor axis.

As shown in Fig. 3A, the camera support member **75** comprises a base surface **77** and a 1/4 inch camera mounting screw **79**, wherein the screw **79** engages a corresponding standard 1/4 inch thread that exists on most camera bodies. The base surface **77** supports the body of the camera, once the mounting screw **79** of the camera support member **75** is fully screwed into the thread (not shown) on the camera body.

Figs. 6A and 6B show two alternative views of the camera support member **75** from the side and above, respectively. The view from above shows the annular shape of the base surface **77**, which supports the body of the camera **16** once the camera **16** is attached to the camera support member **75**. The camera support member also includes a groove region **78** along its annular outer rim for snap fitting into the annular inner rim **126** (see Fig. 3) of the neck **72**.

Fig. 4 illustrates the pair of retaining slots **131** of the collar member **80** (only one shown) located at its upper securing portion **81**, wherein the pair of retaining slots **131** pivotally hold the neck **72** in place. Fig. 5 shows a perspective view from the top and side of the neck **72**. The side view shows the pair of cylindrically shaped contact members **142** for engaging the pair of retaining slots **131** of the collar **80** (illustrated in Fig. 4). Each of the retaining slots **131** comprises a channel opening between two vertical support walls **130**, wherein the walls **130** terminate above a circular recess **132**. The width of the channel between the walls **130** is slightly smaller than the diameter of each pair of the cylindrically shaped contact members **142** (as shown in Fig. 5B). The diameter of the circular recess **132** is approximately the same as the pair of contact members **142**.

As the pair of cylindrically shaped contact members **142** are

pushed into the pair of retaining slots **131**, the width of channel opening (one for each retaining member) increase to accommodate the contact members **124**. As the contact members **142** are pushed past the channel regions and into each recess area **132**, the width of each channel opening returns to its original width. The diameter of the contact members **142** are larger than each channel opening width and therefore, the channel opening closes around the upper surfaces **126** of the contact members **142** (see Fig. 5) as they are pushed into each recess areas **132**. The diameter of the contact members **142** and each recess area **132** are such that the frictional contact between the two (contact members and recess area) provides sufficient securing of the neck **72** to the collar **80** without restricting the pivotal or tilt movement of the neck **72**.

Fig. 8A is a top view of the neck **72**, whereby a tension release mechanism **230** is mounted within the hollow region of the neck **72**. The purpose of a tension release mechanism is to avoid a tendon breaking as a result of forcibly rotating any rotatable members such as the neck or collar **72, 80** in a direction opposing the corresponding motor's torque.

It will be appreciated that forcible rotation of a rotatable member in this way can overcome the tensile strength of a tendon. The tension release mechanism **230** protects the second tendon member **99** from breaking due to the neck **72** being physically forced to tilt when the second motor shaft **98** of the second motor **22** is either stationary (i.e. not rotating), or rotating in the direction opposing that of the physically induced force. This is particularly useful, when users of the system may be of a younger age group and more inclined to curiously try and force the neck **72** to tilt without the motor controlling the tension of the tendon member and consequently the neck **72** movement.

The tension release mechanism **230** comprises a rotatable splined column **232** having a first radius, and a rotatable second column **245** having a second radius. The second radius of the second column **245** is defined as the distance from the center **248** of a circular cross section (e.g. top surface of column as shown in Fig. 8A) of the second column **245**

to the circumference of the circular cross section **249**.

The rotatable splined column **232** has a plurality of spline members **236** extending along its length, wherein each of the spline members **236** on the splined column **232** has an end portion **240**. The first radius of the splined column **232** is defined as the distance from the center **234** of the splined wheel **232** to the tip portion **240** of each spline member **236**.

Both columns **232** and **245** are rotatably mounted on a platform (see Fig. 7 reference number **150**) such that the lateral separation between the centers **234**, **249** of both columns is slightly less than the sum of both the first radius of the splined column **232** and the second radius of the second column **245**. Therefore, as the splined column **232** rotates, a spline member **236** will engage the second column **245** and restrict the rotation movement of the splined column **232**. The outer layer of the second column **245** is made of an elastic type material such as rubber or plastic.

Consequently, if the spline column **232** is rotated with enough torque, the spline member **236** will compress and momentarily deform the outer layer (e.g. rubber or plastic) of the second column **245** causing the spline member **236** to rotate. Once the spline member **236** passes the second column **245**, the portion of the outer layer which engaged the spline member **236** returns to its original shape. If the rotation torque applied to the splined column **232** is beyond a finite torque value, each of the spline members will forcibly rotate past the second column **245**. Therefore, the splined column **232** will rotate in discrete steps, wherein each discrete step is defined by the distance between each of the spline members **236**. The columns **232**, **245** protect the second tendon **99** from excessive tension and the possibility of breaking, as described in the following paragraph.

Fig. 8B is a top view of the second tendon member **99** attached to the neck **72** and tension release mechanism **230**. As previously described, the second tendon **99** passes through the first slit region **74** and the second slit region **76** located at opposing positions on the body of the neck **72**. However, instead of attaching the second tendon **99** to provide a

taut connection between the first slit region **74** and a second slit region **76**, a slack portion **247** of the second tendon **99** is provided, wherein the slack portion **247** is wrapped around the splined column **232** located between the slit regions **74**, **76**. A first portion **250** of the second tendon **99** extends from the splined column **232** through the first slit region **74** and connects to the second motor shaft **98**. A second portion **252** of the second tendon **99** extends from the splined column **232** through the second slot region **76** and connects to the second motor shaft **98**.

Under normal operation, the second motor shaft **98** of the second motor **22** rotates in a first direction and causes the neck **72** to pivot about the second rotation axis **120**. The second tendon **99** applies a downward tension on the first slit **74** and releases the tension from the second slit **76** causing the neck **72** to tilt. Similarly, the second motor shaft **98** of the second motor **22** rotates in a second direction causing the second tendon **99** to apply a downward tension on the second slit **76**, which releases the tension from the first slit **74** and causes the neck **72** to tilt in the opposite direction.

If a user physically forces the neck **72** to tilt without operating the motors **18**, **22**, the excess tension may cause the second tendon **99** to break. With the tension release mechanism **230** in place, the forced tilting action causes the first portion **250** of the second tendon member **99** to experience an increased tension along the direction of arrow **E**, whilst the second portion **252** of the second tendon member **99** experiences a released tension along the direction of arrow **G**. This in turn causes the slack portion **247** of the second tendon member **99** wrapped around the splined column **232**, to try and rotate the splined column **232** in a counter clockwise direction, as defined by arrow **E'**. If the tension on the first portion **250** of the second tendon **99** along the direction of arrow **E** is in excess of a finite limit, each of the spline members **236** of the splined column **232** will forcibly rotate past the second column **245**, causing the splined column **232** to rotate in the counter clockwise direction, as defined by arrow **E'**. As the splined column **232** rotates, the slack portion **247** of the second tendon **99**

is progressively unwrapped from the splined column **245** as forcible tilting of the neck **72** continues. This results in a reduced tension on the first portion **250** of the second tendon **99** along the direction of arrow **E**, thus avoiding breaking the second tendon **99**.

Similarly, if the forced tilting action causes the second portion **252** of the second tendon member **99** to experience an increased tension along the direction of arrow **G**, whilst the first portion **250** of the second tendon member **99** experiences a released tension along the direction of arrow **E**. This in turn causes the slack portion **247** of the second tendon member **99** wrapped around the splined column **232**, to try and rotate the splined column **232** in a clockwise direction, as defined by arrow **G'**. If the tension on the second portion **252** of the second tendon **99** along the direction of arrow **G** is in excess of a finite limit, each of the spline members **236** of the splined column **232** will forcibly rotate past the second column **245**, causing the splined column **232** to rotate in the counter clockwise direction, as defined by arrow **G'**. As the splined column **232** rotates, the slack portion **247** of the second tendon **99** is progressively unwrapped from the splined column **245** as forcible tilting of the neck **72** continues. This results in a reduced tension on the second portion **252** of the second tendon **99** along the direction of arrow **G**, thus avoiding breaking the second tendon **99**.

Referring back to Figs. 3A and 3B, it will also be appreciated that the body of the collar member **80** prevents forcible tilting of the neck **72** beyond absolute rotational limits.

Fig. 9A is a second tension release mechanism **255** identical in operating principle and mechanical structure to the tension release mechanism **230** shown in Fig. 8A and 8B and as previously shown in Fig. 3B. The tension release mechanism **255** protects the first tendon member **95** from breaking due to the collar **80** being physically forced to rotate when the first rotatable motor shaft **96** of the first motor **18** is either stationary (i.e. not rotating), or rotating in the direction in the direction opposing that of the induced force. This is particularly useful when users of the system may be

of a younger age group and more inclined to curiously try and force the collar **80** to rotate without the motor controlling the tension of the tendon member and consequently the collar **80** movement.

The second tension release mechanism **255** comprises a second rotatable splined column **268** and a second rotatable second column **262**, where the lateral separation between the second splined column **268** and the second rotatable second column **262** is identical to that of columns **245** and **232** shown in Figs. 8A and 8B. The rotatable splined column **232** has a plurality of spline members **274** extending along its length.

As shown in Fig. 9A, the second rotatable splined column **268** is placed within a semi-circular recess **280** (also see Fig. 9B) near the base of the second vertical shaft **84** of collar **80**. Both columns **268** and **262** are rotatably mounted on a platform **290**, wherein the platform **290** connects to the second vertical shaft **84**. Therefore, as the second vertical shaft **84** of collar **80** rotates, so does the second tension release mechanism **255**. Fig. 9B is a cross-sectional top view of the second vertical shaft **84** and first tendon **95** without the second tension mechanism **255** in place. As previously described and illustrated in both Figs. 9B and 4, the first tendon **95** is both attached to a fixed point on the circumference of the second vertical shaft member **84** and wrapped around it. By including the tension release mechanism **255**, as shown in Fig. 9A, a second slack portion **286** of the first tendon **95** is provided, wherein the slack portion **286** is wrapped around the splined column **268** located in the semi-circular recess **280** of the second vertical shaft **84**. A first portion **282** of the first tendon **95** extends from the splined column **268** and passes around its circumference and connects to the first motor shaft **96**. A second portion **284** of the first tendon **95** also extends from the splined column **268** and passes around part of the circumference of the vertical shaft member before connecting to the first motor shaft **96**.

Under normal operation, the first motor shaft **96** rotates in a first direction and causes the collar **80** to rotate about the first vertical shaft

108 of the mounting member **100**. As the first motor shaft **96** rotates, the first tendon **95** applies an increased tension on the second vertical shaft **84** of collar **80** in the direction indicated by arrow **I**, whilst the tension on the second vertical shaft **84** in the direction of arrow **H** is reduced. Consequently, the second vertical shaft **84** rotates the collar **80** in a clockwise rotational direction. Similarly, when the first motor shaft **96** of the first motor **18** rotates in a second direction, the first tendon **95** applies an increased tension on the second vertical shaft **84** of collar **80** in the direction indicated by arrow **H**, whilst the tension on the second vertical shaft **84** of collar **80** in the direction of arrow **I** is reduced. Consequently, the second vertical shaft **84** rotates the collar **80** in an opposite anti-clockwise rotational direction.

If the user physically forces the collar **80** to rotate without operating the motors **18**, **22**, the excess tension may cause the first tendon **95** to break. With the second tension release mechanism **255** in place, the forced rotation action causes the first portion **282** of the first tendon member **95** to experience an excess tension along the direction of arrow **H**, whilst the second portion **284** of the first tendon member **95** experiences a released tension along the direction of arrow **I**. This in turn causes the slack portion **286** of the tendon member **95** wrapped around the splined column **268** to try and rotate the splined column **268** in a counter clockwise direction, as defined by arrow **H'**. If the tension on the first portion **282** of the first tendon **95** along the direction of arrow **H** is in excess of a finite limit, each of the spline members **274** of the splined column **268** will forcibly rotate past the second rotatable second column **262**, causing the second splined column **268** to rotate in the counter clockwise direction, as defined by arrow **H'**. As the second splined column **268** rotates, the slack portion **286** of the first tendon **95** is progressively unwrapped from the splined column **268** as forcible rotation of the collar **80** continues. This results in a reduced tension on the first portion **282** of the first tendon **95** along the direction of arrow **H**, thus avoiding breaking the first tendon **95**.

Similarly, if the forced rotation action causes the second

portion **284** of the first tendon member **95** to experience an excess tension along the direction of arrow **I**, the first portion **282** of the first tendon member **95** will experience a released tension along the direction of arrow **H**. This in turn causes the slack portion **286** of the tendon member **95** wrapped around the splined column **268** to try and rotate the splined column **268** in a clockwise direction, as defined by arrow **I'**.

If the tension on the second portion **284** of the first tendon **95** along the direction of arrow **I** is in excess of a finite limit, each of the spline members **274** of the splined column **268** will forcibly rotate past the second rotatable second column **262**, causing the second splined column **268** to rotate in the clockwise direction, as defined by arrow **I'**. As the second splined column **268** rotates, the slack portion **286** of the first tendon **95** is progressively unwrapped from the splined column **268** as forcible rotation of the collar **80** continues. This results in a reduced tension on the second portion **284** of the first tendon **95**, along the direction of arrow **I**, thus avoiding breaking the first tendon **95**.

Figs. 10A and 10B are perspective views of a tendon motor pulley **299** which includes a lower tendon wheel **300** (Fig. 10C) and an upper tendon wheel **302** (Fig. 10D). Tendon motor pulley **299** is a relatively simple assembly which can be used to secure two opposing tendons **310** and **312** (Figs. 11A and 11B) easily and securely.

Specifically, Fig. 10C shows a lower tendon wheel **300** which comprises a disk **301** from which extends two columns **304**, within which are formed two recesses **306** and a central recess **308**. Fig. 10D shows an upper tendon wheel **302** which comprises a disk **321** from which extends two columns **320**, within which are formed two recesses **322** and an extending central hub **324**. As can be understood, columns **304**, **320** and recesses **306**, **322** of upper and lower tendon wheels **300** and **302** are formed so that when lower tendon wheel **300** is coupled to upper tendon wheel **302**, the columns **304** are received in a precision fit within recesses **322** and columns **320** are received in a precision fit within recesses **306**. Further, the central recess **308** is formed so as to receive central hub **324** in

a precision fit.

Disk **301** of lower tendon wheel **300** has a knurled hole **330** which is adapted to receive a motor shaft (not shown). Disk **321** of upper tendon wheel **302** has a bore **332** which is adapted to receive a securing screw (not shown). A securing screw can be used to secure the tendon motor pulley **299** to a motor shaft (not shown). In this way, the tendon motor pulley **299** guides the tendon segment **310** or **312** around a substantially circular path concentric with the attached motor shaft. This ensures the tendon displacement is proportional to the angle of the motor shaft rotation. Likewise, at the other end of the tendon **310** or **312**, a substantial circular tendon segment path centered around the actuating member's rotational axis further ensure the angle of motor shaft rotation is proportional to the actuated member's rotational angle.

Figs. 11A and 11B show how two opposing segments of a tendon **310** and **312** can be secured within tendon motor pulley **299**. In use, tendons 310 and **312** can be looped around central hub **324** and then upper and lower tendon wheels **300** and **302** can be coupled together so that the columns **304** are received in a precision fit within recesses **322** and columns **320** are received in a precision fit within recesses **306**. Most importantly, the central recess **308** is formed so as to receive central hub **324** in a precision fit. A securing screw is then used to secure upper and lower tension wheels **300** and **302** together and to the motor shaft (not shown). It should be noted that the tendons **310** and **312** are double-threaded for added strength.

IMAGE TRACKING SOFTWARE

The operation of the image tracking program (software and microcontroller firmware) is illustrated in the flow diagram of Fig. 12. The general principles of the image tracking program are related to concepts discussed in the research paper authored in part by the applicant entitled "An active stereo vision system for recognition of faces and related hand gestures", R. Herpers, G. Verghese, L. Chang, K. Darcourt, K. Derpanis, R.F.

Enenkel, J. Kaufman, M. Jenkin, E. Milios, A. Jepson and J.K. Tsotsos, Proc. of 2nd Int. Conf. on Audio- and Video-based Biometric Person Authentication, University of Maryland, USA, March, 1999, pp. 211-216.

The process starts when the user activates image tracking system 10 at step **499**. At step **500** and **502** the user selects the image tracking mode or the user positioning, as previously discussed. In user positioning, the user uses an appropriate pointing device (e.g. computer mouse or trackball) to position the digital video camera so that it displays a desired image on the computer screen or monitor. In contrast, in image tracking mode, the image of a human subject is continuously tracked by the digital video camera using the skintone tracking algorithm. As the subject moves, the camera automatically tracks the subject's movement and displays the image on the screen or monitor.

Now referring to Figs. 12 and 14, in a step **504** the user may select any desired camera position, wherein the user control screen **50** (see Fig. 14) allows the user to select a desired camera pointing position by selecting the left arrow button **52**, right arrow button **54**, up arrow button **58** and down arrow button **56**. Alternatively, the user may click any point in the displayed image frame to direct the camera to center that point. In a step **506**, each time the arrow buttons (**52**, **54**, **56**, **58**) are clicked on (e.g. by a mouse) or an arrow key if pressed on the keyboard, a position movement instruction frame is generated for the purpose of providing camera movement in the direction of the arrow button clicked on. Continuous movement occurs while the button or key is pressed. In a step **520**, the movement instruction frames corresponding to the activated (pressed or clicked on) arrow buttons (**52**, **54**, **56**, and **58** as shown in Fig. 14) are converted to specific pulse width modulated (PWM) signals which generate the movement of the motors **18**, **22**.

Each time a particular arrow button is activated a specific PWM signal advances the position of the motors, based on the arrow button activated. If the left arrow button **52** or right arrow **54** button is clicked, the first motor **18** generates the pan movement for the position manipulating

device **70** and camera **16**. If the up or down arrow button **58**, **56** is clicked, the second motor **22** generates tilt movement for the position manipulating device **70** and camera **16**.

Two additional movement methods which can be implemented within the image tracking software of the present invention are the mouse-tracking and mouse-clicking modes. Specifically, in the mouse-tracking mode, all two dimensional mouse movements are translated to camera movements, until the user releases the mouse button. In the mouse-clicking mode, the software allows the user to click on a point in the image displayed on-screen and responds by moving to center in on that point.

In addition to the arrow buttons, mouse-tracking and mouse-clicking modes, movement of the position manipulating device and camera can be achieved through voice commands such as: "LOOK LEFT", "LOOK RIGHT", "LOOK UP", AND "LOOK DOWN".

In step **500**, if the image tracking mode is selected, the program moves to a step **508**, wherein the digital video image from the camera **16** is stored for subsequent image processing. The image data output from the digital video camera **16** is in 24-bit (RGB-24) color format transmitted at a rate of 30 Hz. In a step **510**, the retrieved stored digital image from the camera is radially scanned from the center of the digital image towards the outer border of the image in order to identify a region of skintone bordered by regions of non-skintone. The point on the digital image at which the radial scanning first starts can be from the center of the image, the previous centroid or defined by the user following a mouse click. In an alternative embodiment, it is possible to provide random access to camera image memory without entire image transmission and no frame rate limitation. In a further alternative embodiment, the tracking algorithm will run on a microcontroller within the device and not on the host computer.

In a step **512**, if a region of skintone is not detected, the program returns to step **510**, where the next digital image frame from the camera **16** is radially scanned for the purpose of identifying a region of

skintone. This process continues until a region of skintone is detected. If the radial scan detects a region of skintone bordered by non-skintone, in a step **514**, the centroid of the region of skintone is determined, wherein the centroid identifies the central position of the region of skintone. Once the centroid of the digital image has been determined, in a step **516**, the coordinate position of the centroid is calculated. In a step **518**, the coordinate position of the centroid is compared with image center coordinates. The coordinate locations of both the centroid and the center of the image are processed in order to determine the displacement of the centroid's coordinate location from the coordinate location of the center of the image. In the step **506**, the displacement of the centroid's coordinate location from the center of the image enables the generation of movement instruction, wherein the instruction frames specify camera **16** movement to effect displacement of the centroid to the center of the image.

In a step **520**, the movement instruction frames corresponding to the difference in the coordinate positions of the centroid and center of the image are converted to specific pulse width modulated (PWM) signals, where the PWM signals generate the movement of the motors **18**, **22**. Depending on the position of the centroid relative to center of the image, specific instruction frames are converted to PWM signal which move each motor **18**, **22** independently based on whether the corresponding instruction frame determines horizontal pan movement or vertical tilt movement. For example, if the centroid is above and to the left of the center of the image, the first motor **18** will receive a PWM signal for initiating the pan movement of the position manipulating device and camera, wherein the pan movement of the camera causes the centroid to move to the left and toward the center of the image. Similarly, the second motor **22** will receive a PWM signal for initiating the tilt movement of the position manipulating device and camera, wherein the tilt movement of the camera causes the centroid to move downward toward the center of the image. During image tracking mode, the received digital images from the camera **16** are continually stored and radially scanned for the purpose of calculating the coordinate position of the

new centroid within each scanned image. After step **520**, the process again determines whether the user desired to be in user positioning or in automatic tracking mode at step **500** and either executes step **508** or step **500**, respectively.

Figs. 13A, 13B and 13C show perspective side, front and top views of an alternative embodiment of the position manipulating device **340** of the present invention, respectively. The second position manipulation device **340** provides a third rotational movement and a fourth rotational movement in addition to the first and second rotational movements which refer to the already described pan and tilt movements.

The second position manipulating device **340** comprises a first motor device **405**, a second motor device **377**, a third motor device **381** and a fourth motor device **379** for actuating the movement of a first rotatable member (inside annular rim member **342**) , a second rotatable member **343**, a third rotatable member **346** and a fourth rotatable member **348** respectively.

The first motor **405** has a first rotatable shaft member **407**, wherein the first motor shaft is drivingly connected to the first rotatable member (not shown). The first rotatable member is a major rotation wheel which has a first rotational movement within a ball bearing filled annular rim member **342**. The first rotational movement is referred to as a major pan rotation movement (horizontal rotation), which is defined by a first plane of rotation **430** about a first rotation axis **432**. It will be appreciated that in accordance with the present invention the first motor shaft may incorporate a first tendon member (not shown) to actuate movement of the first rotatable member.

The second motor **377** has a second rotatable shaft member **477**, whereby the rotation of the second shaft **477** is coupled by a second tendon member **378** to the second rotatable member **343**. The second rotatable member is a tilt bar **343**. The tilt bar **343** undergoes a second rotational movement, wherein the second rotational movement is a tilt movement defined by a second plane of rotation **434** about a second

rotation axis **436**.

The third motor **381** has a third rotatable shaft member **390**, whereby the rotation of the third shaft **390** is coupled by a third tendon member **358** to the third rotatable member **346**. The third rotatable member **346** is a first minor rotation wheel **346**. The first minor wheel **346** undergoes a third rotational movement, where the third rotational movement is a first minor pan rotation (horizontal rotation), which is defined by a third plane of rotation **440** about a third rotation axis **442**.

Similarly, the fourth motor **379** has a fourth rotatable shaft member **479**, whereby the rotation of the fourth shaft **479** is coupled by a fourth tendon member **360** to the fourth rotatable member **348**. The fourth rotatable member is a second minor rotation wheel **348**. The second minor wheel **348** undergoes a fourth rotational movement, where the fourth rotational movement is a second minor pan movement (horizontal rotation), which is defined by a fourth plane of rotation **445** about a fourth rotation axis **447**. It will be appreciated that motors **405**, **381**, **377**, **378** are servo-motors identical to those described in the previous embodiment of Figs. 3A. It will also be appreciated that different types of motors may be used without departing from the scope of the present invention described and illustrated herein.

An image capture device comprising a first digital video camera **354** and a second digital video camera **356** are each enclosed in a first camera housing **350** and a second camera housing **352** respectively. The first camera housing **350** is attached to the first minor wheel **346** and the tilt bar **343** by means of securing member **366**. Similarly, the second camera housing **352** attaches to the second minor wheel **348** and tilt bar **343** by means of securing member **362**.

The tilt bar **343** attaches to a spring biasing member (not shown) and to the major wheel by means of securing members **383** and **364** respectively. As the tension on the second tendon **378** increases with the rotation action of the second shaft **477** , the tilt bar **343** tilts backward in the direction of arrow **A** against the tension in the spring member (not

shown). Conversely, as the tension on the second tendon **378** is reduced by rotating the second shaft **477** in the opposite direction, the tilt bar **343** tilts forward under the counter active force of the spring member (not shown).

Both the first minor wheel **346** and the second minor wheel **348** are also spring loaded using a first and second tension biasing spring (not shown). As the tension on the third tendon member **358** increases with the rotation action of the third shaft **390**, the first minor wheel **346** rotates against the tension force of the first tension spring. Also as the tension on the third tendon **358** is reduced by rotating the third shaft **390** in the opposite direction, the first minor wheel **346** rotates in the opposite direction under the counter active force of the first tension spring. Similarly, the tension on the fourth tendon member **360** increases with the rotation action of the fourth shaft **479**, where the second minor wheel **348** rotates against the tension force of the first tension spring. As the tension on the fourth tendon **360** is reduced by rotating the fourth shaft **479** in the opposite direction, the second minor wheel **348** rotates in the opposite direction under the counter active force of the second tension spring.

Consequently, both the first and second cameras **354**, **356** undergo first and second minor pan movement, tilt movement and major pan movement by individually actuating the first minor wheel **346**, second minor wheel **348**, tilt bar **343** and major rotation wheel (not shown). The configuration and positioning of the tendons **378**, **358**, **360**, motors **405**, **381**, **377**, **378** and rotatable members **346**, **348**, **343**, (major wheel member) is such that the axial rotation of each rotatable member is independent of all the other rotatable members. This means that rotating individual members about their axes does not restrict or affect axial rotations or orientations of other rotatable members.

This is achieved by ensuring that the second rotation axis **436** of the tilt member **343** (second rotatable member) rotates about the second tendon member **378** and the stationary first rotation axis **432** of the major wheel (first rotatable member). The second tendon **378** is oriented such that a substantial portion of the second tendon is aligned with the stationary first

rotation axis **432**. In order words the second tendon **378** is also required to be connected between the tilt member and the second motor shaft member **477**, such that a fixed point on the second tendon **378** intersects the stationary first rotation axis **432** at a first axis intersection point in a manner whereby the fixed point and intersection point are stationary relative to each other during rotation of the major wheel. Also, the fixed point on the second **378** tendon is fixed relative to the second rotatable member referred to as tilt member **343**. The tilt member **343** and the first major wheel are now independent of each other in that rotation of one rotatable member does not affect the axial orientation of the other. Hence, no tension or release is induced in the second tendon **378** by rotating the first major wheel.

The first and second minor rotation wheels **346**, **348** are also independent of the first major wheel movement. This is accomplished by ensuring that no tension or release in tendons **358** or **360** is induced by first major wheel movement. This is accomplished by ensuring that a point on the third tendon **358** is fixed relative to the first minor rotation wheel **346** to which it connects during major wheel rotation. A similar independence is achieved by ensuring that a point on the fourth tendon **348** is fixed relative to the second minor rotation wheel **348** during major wheel rotation.

In order to achieve a fixed point along a tendon to its rotatable member (tilt member, first minor wheel, second minor wheel or major wheel or motor shaft member), a flexible fixed length tubing may used to thread the tendon through. As shown in Figs. 13B and 13C, the third and fourth tendons **358**, **360** use plastic tubing **410**, **415** to connect motor shafts **390**, **479** to the rotatable members (first minor wheel **346** and second minor wheel **348**). The plastic tubing must constrain the tendon's shape and provide little friction to the movement of the tendon within the tube. The ends of each tube are fixed relative to the respective rotatable member throughout all other movements. Since the tube constraining each tendon is of fixed length, no tension or release is induced by movements other than actuation of the motor connected directly to the tendon. Axial orientations of the four rotatable members are thus independent of one another.

The position of the motors **405**, **381**, **377**, **378** within the position manipulation device **340** ensure that no motor is responsible for movement of the load or mass of any other motor. It will be appreciated that in accordance with the present invention, the first motor **405** can be positioned below the major wheel and rim member **342**, where the first motor **405** can generate movement of the first major wheel by coupling the first motor shaft **407** movement through the use of a first tendon member. Fig. 13A shows that the first motor **405** directly mounted on the major wheel, where the first motor shaft member **407** rotates about a first shaft rotation axis which is longitudinally concentric within the first motor shaft **407**. The second motor shaft member **477** rotates about a second shaft rotation axis which is longitudinally concentric within the second motor shaft **407**. Also, the third and fourth motor shaft members **390**, **479** rotate about a third shaft rotation axis and a fourth shaft rotation axis respectively.

The third and fourth shaft rotation axes are also longitudinally concentric within the third and fourth shaft members **390**, **479**. In accordance with the present invention, the first, second, third and fourth rotation axes of motors **405**, **381**, **377**, **378** are stationary and fixed relative to one another, each motor generates independent movement of the rotatable members and each motor does not carry the load or mass of any of the other motors.

In the alternative embodiment shown in Figs. 13A and 13B the first and second digital video cameras provide stereo vision capability, wherein 3-dimensional digital image frames are generated. Each of the first and second video cameras generates 2-dimensional image frames which are processed by means of image processing software in order to provide corresponding 3-dimensional image frames. Whilst stereo vision is already known in the art of robotics and image processing, the use of digital image frames with additional depth perception (third dimension of view) provides more robust tracking capabilities with user enhanced three dimensional viewing using stereo glasses.

The instant invention also incorporates voice activated

command options, which can be set up from the user control screen. This enables manual tracking of an object by the user by means of user defined voice commands. As previously discussed, the direction indicator **71** is mounted on the front surface of position manipulation device **70** and indicates to the user that the unit is in operation and further which direction (UP, DOWN, LEFT, RIGHT or a combination thereof) the camera is moving in.

Fig. 14 shows the user control screen **50** generated when the user interface software is first started. The user CONTROL SCREEN™ **50** includes a left arrow button **52**, a right arrow button **54**, an up arrow button **58**, a down arrow button **56**, Tuner button **62**, Tool Panel button **66** and a Track button **64**. The Track button **64** turns the image tracking feature ON and OFF. Once the image tracking feature is OFF, the left arrow button **52**, right arrow button **54**, up arrow button **58** and down arrow button **56** can be used to manually move the camera to display a the camera's video stream in the display portion **60** of the control screen **50**. With the image tracking switched ON, the camera will continuously track the image of the user in its field of view. The Tuner button **62** enables the user to fine tune the image settings, such as adjusting video levels for providing reliable tracking and optimizing the images shown on the display portion **60**. The Tool Panel button **66** enables the user to control the more advanced features of the image tracking system **10**, such as setting up video conferencing sessions, manipulating the display portion **60** size, voice command features and image control functions. Other features of the user interface software include capture of still camera images and adjusting the speed of image tracking.

It should be noted that image tracking system **10** provides a number of significant advantages to videoconferencing and computer users. Since the images are processed using an image processing algorithm, the servo-motors generate rotational movement for the position manipulating device and camera, such that the image of the user is constantly tracked. Also, the position manipulating device provides a configuration of

independent stationary servo-motors in order to avoid “motor loading” and to provide efficient movement of the structure using low torque, low cost servo-motors.

It should be understood that various modifications can be made to the preferred and alternative embodiments described and illustrated herein, without departing from the present invention, the scope of which is defined in the appended claims.